# MECHANIZATION OF PRODUCTION

UDC 666.65:621.926

## THE USE OF A COUNTERCURRENT JET MILL IN THE PRODUCTION OF INSULATING CERAMICS

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Translated from Steklo i Keramika, No. 8, pp. 29 – 31, August, 2006.

The possibility of using a countercurrent jet mill in preparing molding powder to make insulating ceramics is considered. The process scheme is described and technical specifications of products are given. The auditors draw the conclusion that the stages of diluting clay in water and its milling, homogenization, and drying can be replaced by the stage of fine milling using a countercurrent jet mill.

The specifics of ceramic production includes molding preforms from initial powder and their subsequent firing. The flow properties of ceramic mixtures and properties of preforms in molding significantly depend on the granulometric composition of mixtures.

Diverse mixtures can be divided into two large groups: coarse-grained (500 – 1000 μm and more) and fine-grained (below 50 – 100 μm) [1]. Intermediate grain sizes are almost never used in ceramic technology. The fine-dispersion group also includes a "highly-dispersed" subgroup where all materials are ground to a size of the order of a micron or a fraction of a micron. The application areas of each group of mixtures and their purposes and milling methods differ significantly.

Let us consider the process of preparing fine-grained mixtures used in the production of household and electrotechnical porcelain, certain facing materials, and nearly all types of engineering ceramics. These products have significant volume variation in firing (usually linear shrinkage 10 – 20%) and in most cases belong to "sintered' materials (total porosity not more than 5 – 10%, open porosity from 0 to 1 – 2%). Fine-grained and highly dispersed powders are usually produced in batch ball mills and sometimes in vibration mills.

The domestic industry nearly never uses continuous mills in the production of fine ceramics, and only recently have jet mills started to mill nonplastic components.

Comparative analysis of published sources suggests that jet milling has significant advantages. First, the required high degree of milling can be more easily achieved in a mill in which two jets of material collide with each other. Second, they are convenient for manufacturers producing relatively small batches of products, for instance, technical ceramics, which does not require a high-output mill intended for tens and even hundreds tons of powder daily. Furthermore, milling materials in ball or vibration mills makes it difficult to avoid contamination of mixtures.

Therefore, we proposed using a countercurrent jet mill for the production of insulating ceramics for voltages up to 1000 V based on aluminosilicate ceramic mixtures (group 100, subgroup 111, GOST 20419–83) at the stage of milling and introduction of additives. The technological production scheme is shown in Fig. 1.

In choosing the milling conditions one should take into account the following fact. Milling in a ball mill is performed adding water to facilitate the destruction of solid particles and achieve a high degree of dispersion. This aggravates the wear of the milling bodies, and, moreover, material after this milling requires thermal treatment (drying) to obtain molding powder of the desired moisture level (usually 6 – 10%). In a jet mill, on the contrary, efficient dry milling is combined with drying. In this case we avoid clotting of the highly dispersed particles, and the finished product does not require drying. Thus, we eliminate one of the most energy-consuming operations. Furthermore, the assumption was made that, in addition to being an effective milling device, a jet mill after a slight modification could integrate two processes: milling and separation of impurities that are hard to grind.

To solve this problem we have developed a countercurrent jet mill with a totally new design of the milling chamber with adjustable parameters. We strove to increase the milling efficiency (RF patent No. 2188078). The milling plant includes a breaking-eddy classifier, a screw feeder, a cyclone, and a bag filter for fine purification.

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0361-7610/06/0708-0274 

The mill was installed and tested at the division of fine technical ceramics of the Tekhnolog Research-and-Production Complex (Belgorod) to determine its process parameters in milling clay from the Krasnoyaruzhskoe deposit (Belgorod Region) that is used in ceramic production based on aluminosilicate ceramic mixtures.

The testing of milling clay in the countercurrent jet mill was performed in continuous production. Precrushed initial material (fraction below 5 mm) of moisture not more than 7% was fed by a screw feeder to milling. The energy carrier was delivered via a pipeline from the compressor receiver under the pressure of 0.5 MPa.

The granulometric composition of clay powders ground in the countercurrent jet mill was determined by sedimentation analysis. The powders were compared with clay powders from the same deposit produced by moist milling in a ball-tube mill.

The granulometric composition of clay milled in the jet mill was as follows (%): fraction 0 – 5 μm, 96.9; 5 – 10 μm, 2.1; 10 – 15 μm, 0.5; 20 – 25 μm, 0.1; 25 – 30 μm, 0.1; over 30 μm, 0.1. For comparison we give the composition of the sample milled in a ball mill of diameter 0.75 m and length 0.5 m (%): fraction 0 – 5 μm, 32.0; 5 – 50 μm, 51.0; and 50 – 100 μm, 17.0

Thus, the majority of the particles of the sample ground in the ball mill are within 5 – 50 μm (over 50%). The content of particles over 30 μm in the sample milled in the countercurrent jet mill is 0.1%. The granulometric composition of the sample obtained in this mill significantly surpasses the sample milled in the traditional way, since particles of diameter below 5 μm prevail (over 96%) and, consequently, the dispersion and quality of the material is better.

To corroborate the above, the laboratory of the Tekhnolog Research Complex identified the main properties of products made from finely dispersed clay powders. The initial samples were three types of materials:

– clay from Krasnoyaruzhskoe deposit milled in the countercurrent jet mill, sample 1;

– clay from the Krasnoyaruzhskoe deposit milled in the ball mill, sample 2;

– clay from the Latnenskoe deposit milled in the ball mill, sample 3.

Each material was used to mold samples of diameter 15 and height 30 mm by semidry molding. Then the samples were fired in a muffle furnace at 1130, 1150, and 1170°C.

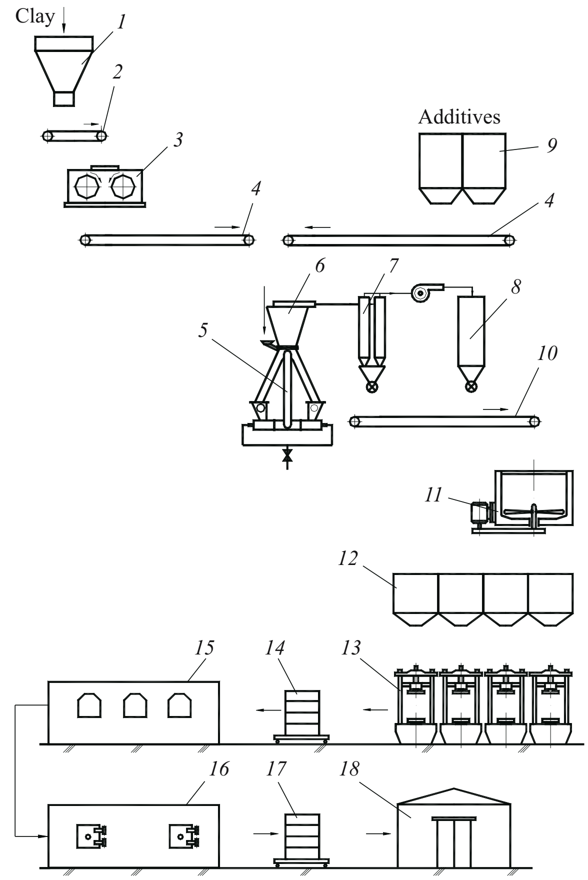


**Fig. 1.** Technological scheme of the production of insulating ceramics: *1*, *9*) hoppers; *2*, *4*, *10*) feeders; *3*) stone-removing rolls; *5*) countercurrent jet mill; *6*) separator; *7*) group of cyclones; *8*) fine purification filter; *11*) granulator; *12*) distributing bunker; *13*) press; *14*, *17*,) cars with trays; *15*) drying chamber; *16*) furnace; *18*) warehouse.

Such parameters as shrinkage ε, apparent density $\rho_{ap}$, apparent porosity $P_{ap}$, and water absorption $W$ were determined. The main properties of the considered samples are listed in Table 1.

It can be seen that shrinkage in sample 1 caused by temperature rising from 1130 to 1170°C grew by 17.5%, whereas in the two other samples the shrinkage grew by 87.5 and 44.1%, This shows that in the case of the finer milling the sintering of the molded preform is more intense and favorable to the product. Just this one factor can lower the sintering temperature.

**TABLE 1**

| Temperature of firing samples, °C | Sample 1 | | | | Sample 2 | | | | Sample 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ε, % | $\rho_{ap}$, g/cm$^3$ | $P_{ap}$, % | $W$, % | ε, % | $\rho_{ap}$, g/cm$^3$ | $P_{ap}$, % | $W$, % | ε, % | $\rho_{ap}$, g/cm$^3$ | $P_{ap}$, % | $W$, % |
| 1130 | 5.7 | 2.20 | 16.4 | 7.5 | 1.6 | 2.06 | 21.8 | 10.6 | 3.4 | 1.75 | 30.0 | 20.3 |
| 1150 | 6.4 | 2.23 | 13.9 | 6.2 | 2.5 | 2.08 | 20.1 | 9.6 | – | – | – | – |
| 1170 | 6.7 | 2.23 | 10.7 | 4.8 | 3.0 | 2.09 | 19.3 | 9.3 | 4.9 | 1.77 | 35.0 | 19.8 |

Increasing the degree of milling until the prevalent grain size is less than 5 μm leads to an increased total surface area of the phase boundary, decreases the mean curvature radius of convex sites, increases excessive surface energy, and decreases the distance between the vacancy sources and receivers in the system; the overall effect of these factors in sintering is manifested in the growing density and mechanical strength of the material under heat treatment. Thus, the apparent density of sample 1 at 1170 is equal to 2.23 g/cm$^3$, whereas in samples 2 and 3 this parameters is lower: 2.09 and 1.77 g/cm$^3$, respectively.

The porosity decrease corresponding to the density increase as well is more intense in the sample made of the material ground in the jet mill. The porosity of sample 1 at the firing temperature of 1130 amounts to 16.4 %; for sample 2, 21.8%; and sample 3, 30%. As the firing temperature grows to 1170°C, the porosity of samples 2 and 3 decreases, but only slightly, and is equal to 19.3 and 30%, respectively, whereas the porosity of sample 1 decreases by 34.8 % and reaches the absolute minimum (10.7%) of all samples analyzed.

A similar trend is observed regarding another parameter, i.e., water absorption, where sample 1 has the lowest value at all firing temperatures.

Thus, clay powders milled in a countercurrent jet mill are preferable, since they yield better-quality finished product. The properties of these powders satisfy the requirements imposed on ceramic mixtures for electroinsulating ceramics intended for voltages up to 1000 V (TU 3493-002-02066339–98).

Industrial testing of the countercurrent jet mill demonstrated high reliability and efficiency of this type of milling machine for milling clay that is intended for producing ceramics from aluminosilicate ceramic mixtures. Consequently, the stages of clay dilution in water, milling, homogenization, and drying can be replaced by the fine milling stage using the countercurrent jet mill in the production of high-precision articles from fine ceramics.

## REFERENCES

1. *Chemical Technology of Ceramics and Refractories* [in Russian], Stroiizdat, Moscow (1972).